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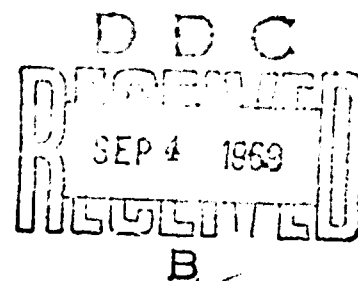
NRL Report 6932

# Corrosion Resistance of Some Common Metals to Concentrated and 6% Solutions of Light Water Fire-Extinguishing Agent

A. W. BERTSCHY AND H. B. PETERSON

*Combustion Suppression Research Center*

August 8, 1969



**NAVAL RESEARCH LABORATORY**  
Washington, D.C.

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## ABSTRACT

A study has been made concerning the corrosion resistance of a group of common construction metals that might come in contact with the fire-extinguishing agent known as Light Water. The metals examined were exposed to concentrated Light Water material and to 6% solutions of Light Water prepared with sea water and with fresh water.

Type 304 stainless steel and titanium were virtually unaffected by any of the liquids. Overall weight losses for type 6061 aluminum alloy were low, on the order of 2 milligrams per square decimeter per day (mdd). However, localized pitting was observed. Monel had losses of 5 mdd with the Light Water concentrate. The copper-base metals immersed in the concentrate exhibited weight losses in the range of 10-13 mdd, while steel, lead, and zinc were in the 18-40 mdd range.

The corrosive effect of 6% solutions prepared with fresh water was generally not different than with fresh water itself, except for the copper-base alloys. The 6% solutions prepared with sea water gave results generally not different than with sea water itself.

A comparison of the Light Water concentrate test results with earlier tests conducted on protein-type foam concentrates shows the latter to be considerably more corrosive. The limits for corrosion as set forth in the proposed military specification for Light Water fire-extinguishing concentrate are lower than those in the current federal specification for protein foam concentrate.

## PROBLEM STATUS

This is an interim report. Work on the problem is continuing.

## AUTHORIZATION

NRL Problem C05-19  
Project SF 015-07-02-3350  
Subproject S 4643, Task 12081

Manuscript submitted May 9, 1969.

## **CORROSION RESISTANCE OF SOME COMMON METALS TO CONCENTRATED AND 6% SOLUTIONS OF LIGHT WATER FIRE-EXTINGUISHING AGENT**

### **BACKGROUND**

Since the development and introduction in 1964 of Light Water as a fluorinated film-forming type of fire extinguishing agent (1), the question of its behavior towards metallic construction materials and its effect on elastomers has been of interest (2). The present study was initiated to obtain data on the behavior of some of the common metals when in contact with Light Water and is similar to a study conducted previously with protein foam concentrate (3).

### **INTRODUCTION**

#### **Light Water Formulations**

In present usage, Light Water will be encountered in two forms as related to corrosion. One form is the concentrate as it is received from the manufacturer and handled until its time of application to a fire, at which time it is diluted with water by passing through a proportioner to create a 6% solution. This is the normal procedure for Light Water used in major aircraft rescue and fire-fighting vehicles on air stations and airports. In smaller, self-contained, fire-fighting apparatus, such as the TAU (Twinned Agent Unit) and SB/TAU (Shipboard Twinned Agent Unit) units, the Light Water concentrate is diluted and stored as a premix solution (the second form) prior to the time of application. In addition, in large installations such as aircraft carriers it would be desirable to have a third form—a combination of proportioning and premix systems—because then it would be possible to keep the long pipelines downstream of the proportioner full of dilute solution at all times and thus reduce the time in getting agent onto the fire. (This latter situation does not now exist because 6% protein foam solutions are not stable on standing.)

Therefore, the three different Light Water situations which present themselves in the Navy with respect to potential corrosiveness are the Light Water concentrate, the concentrate diluted with fresh (tap) water, and the concentrate diluted with sea water.

#### **Light Water Properties**

The most recent concentrate formulations of Light Water require pH values as low as 4.5 to maintain their stability during storage. This acidic condition influences its potential corrosivity toward several of the common metals. In the diluted form the pH of the concentrate is of less significance. Another factor with both the concentrate and the dilute solutions is their extremely low surface tension. This property may be influential in causing these agents to degrease and clean metal surfaces and also to penetrate minute cracks and pores.

#### **Light Water Concentrates**

The present study covered the period during which a new concentrate, the FC-195 which would be compatible with sea water as well as fresh water and would replace the

older FC-194, was introduced. As a result, much of the early work already completed on FC-194 had to be repeated with FC-195, and an additional diluent variable, sea water, had to be included, as well as a new cupro-nickel metal representing existing shipboard fire mains. This prolonged the period of preparation of this report. The new FC-195 formulation meets all the requirements of the latest draft (dated February 18, 1969) of the proposed military specification submitted to the Naval Ship Systems Command.

Several different formulations of Light Water concentrate were employed in the test work. The FC-194 was from lots manufactured in July 1967. This material was made to meet the requirements (4) of MIL-F-23905B and was best suited for dilution with fresh (tap) water. Four experimental formulations of Light Water made for dilution with either fresh or sea water were utilized: L-2265, L-2223, L-2242, and L-2264. Of these experimental concentrates prepared by the manufacturer, L-2265 was ultimately chosen for the final product because of its superior fire-extinguishing characteristics and was designated as FC-195.

#### Diluent Water

The tap water used in the subject tests was from the Washington, D.C., city water system. The synthetic sea water was made up from tap water and a commercially obtained\* mixture of dry salts purchased to meet the ASTM Standard (5).

### EXPERIMENTAL PHASE

#### Metal Specimens

The metals exposed during this study were selected either on the basis of their known resistance to corrosion or because of their present existence in shipboard fire-fighting systems. The individual metal specimens used in making up the test coupons were drawn from metal stocks at the Laboratory; detailed metallurgical data was not available in all cases. The known identifications of the metals used were as follows:

Stainless steel: 18-8; class 304; hot rolled; annealed; pickled; polished on one side.

Monel: approximately 70% nickel.

Aluminum: 6061-T6; mill finish.

Brass: commercial; half hard; mill finish; yellow; 64-68.5% copper.

Copper: light temper; mill finish.

Steel: cold rolled.

Cupro-Nickel: copper 90%; nickel 10%.

Lead: grade C; 99.9% lead.

Zinc:

Titanium:

Formed tubing: copper 90%; nickel 10%; actual pieces of shipboard piping obtained from Naval Shipyard, Philadelphia.

Dissimilar metal couplings were made by silver brazing cupro-nickel strips to strips of bronze, stainless steel, monel, brass, and copper.

#### Test Procedure

Corrosion tests were conducted using ASTM standards as a basic guide (6,7). By nature, corrosion testing is difficult to standardize because of numerous variables. Consequently, the ASTM methods are somewhat arbitrary and open to modification to meet the objectives of a particular application.

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\*Lake Products Company, Inc., St. Louis, Missouri.

Sample test specimens were prepared by cutting, with a shear, strips from sheet stock to an oversize of 3-5/8 in.  $\times$  5/8 in. These were further reduced to a finished size of 3-1/2 in.  $\times$  1/2 in. with a milling machine. Additional preparation consisted of numerically stamping, descaling, and thoroughly cleaning each specimen. The latter treatment included the following steps: degreasing, acid or alkali dip, steel wool scrubbing, water and acetone rinses, air drying, and final storage in a desiccator. Before each specimen was placed in a test solution, measurements were made of its exact dimensions with a micrometer and it was weighed to an accuracy of  $\pm 0.1$  mg.

For testing purposes, the specimens were individually stored in 1-oz. glass vials. The vials were 3-3/4 in. high and 15/16 in. in diameter and had a 10/32 in. opening. They were threaded to hold a plastic cap which was lightly screwed on so air could be readily admitted. In order to minimize any galvanic reaction or possible loss of metal, no specimen holder was used. The specimen was merely rested in a vertical position in a vial on its 1/2 in. edge. Approximately two-thirds of its height was immersed in the test solution and one-third exposed to the enclosed air.

The cupro-nickel shipboard piping specimens required a modified procedure because the only samples available were in the form of 1/16 in. thick wall, 1-3/16 in. I.D. tubing. The tubing was cut into 7/16 in. long cylinders, numbered, cleaned, weighed, and placed individually in 5-1/2-oz. wide-mouth sample bottles. They were immersed to approximately two-thirds of their height and supported in an upright position with a small glass bottle.

In most instances duplicate metal exposures were made. The liquids used were Light Water concentrate, 6% Light Water concentrate in tap water, and 6% Light Water concentrate in synthetic sea water. Specimens immersed in plain tap water and synthetic sea water were used as controls. The prepared test samples were placed in storage trays and set in an air-circulating constant-temperature oven. The exposure period was 38 days at a controlled temperature of  $35 \pm 1^\circ\text{C}$  ( $95^\circ\text{F}$ ).

At the conclusion of the exposure period, the metal specimens were removed from the test solutions carefully to avoid losing any adhering corrosion scale material. The specimens were cleaned by scrubbing with a bristle brush or rubbing with a rubber stopper. Treatment with weak solutions of  $\text{HNO}_3$  and  $\text{NaOH}$  was also effective for removing loose scale. After being washed, the specimens were immersed in acetone and placed in a desiccator before weighing. The resulting weight loss data was used to compute the rate of corrosion expressed as mdd (milligrams per square decimeter per day).

A number of different metals were bonded to strips of cupro-nickel by a silver solder joint to detect any possible dissimilar-metal-couple corrosion problems. A situation like this is created through the fabrication of piping systems aboard ship where the pipe and fittings are joined with hard solder. After soldering the strips together they were placed in FC-195 concentrate in the same manner as the single metal specimens and for the same exposure time.

## RESULTS

As a matter of related information the following pH determinations were made on the immersion liquids employed:

<u>Liquid</u>	<u>pH</u>
Tap (fresh) water	7.8
NRL synthetic sea water	8.6
Generally accepted value for natural sea water	8.0-8.2
FC-195 concentrate	4.7
6% FC-195 in sea water	6.3

The weight losses suffered by the exposed metals, taken as a direct indicator of their susceptibility to corrosion, have been plotted in Figs. 1 and 2.

During the test period, several inspections were made of the samples. The obvious changes noted were the formation of some corrosion growth scale on the metals and the development of colored solutions resulting from the solubility of some of these corrosion by-products.

On removal after exposure and cleaning, no evidence of galvanic action could be detected between pairs made of cupro-nickel and bronze, stainless steel, monel, brass, or copper immersed in FC-195 concentrate.

## DISCUSSION

### Individual Metals

In comparing the results of Fig. 1 on a metal-by-metal basis it may be seen that type 304 stainless steel was unaffected by any of the liquids, and on this basis it should be an excellent metal for all situations involving Light Water. From other experiences, however, stainless steel is known to be susceptible to attack after fabrication operations such as welding, which sensitizes the metal structure. For this reason stainless steel should be handled with some caution.

At present stainless steel tanks are being used for holding Light Water/fresh water solutions on the "second generation" Shipboard Twin Agent Units manufactured by the Fire Control Engineering Company for aircraft carrier applications.

Titanium was relatively unaffected by immersion in the FC-194 concentrate, having a corrosion rate of only 0.068 mdd. Fresh water and 6% FC-194/fresh water showed no corrosive effect on titanium.

Even though monel was more resistant than the copper alloys to the concentrates (its only apparent change was a slight tarnishment), it was less resistant than stainless steel and titanium. Weight losses for monel were in the range of 3-5 mdd.

Aluminum alloy 6061 proved very resistant to all liquids strictly on a weight loss basis. Although the total weight losses were very low, the attack was characterized by pitting, which concentrated the metal removal. This type of corrosion often results in localized perforations of field equipment. The pits were observed to occur randomly over the specimen surface. The other metals which underwent weight loss also developed pits, but to a lesser degree, and the pits for these metals were confined to the air-liquid interface region of the metal coupon.

Aluminum alloy is used as the Light Water/fresh water solution container on the Twin Ball Fire Fighting Units located at many naval air stations. No reports of corrosion have been reported in the five years that these units have been in service.

The copper-base alloys acted somewhat similarly as a group, their corrosion rates lying between stainless steel and titanium on the one hand and steel on the other. Weight losses for the group were highest with the Light Water concentrates, being in the range of 10-13 mdd. Light Water solutions made with sea water were hardly more corrosive than sea water itself. In fact, with the pure copper the Light Water had an inhibiting effect. Light Water solutions with fresh water removed metal at rates of 2-8 mdd.

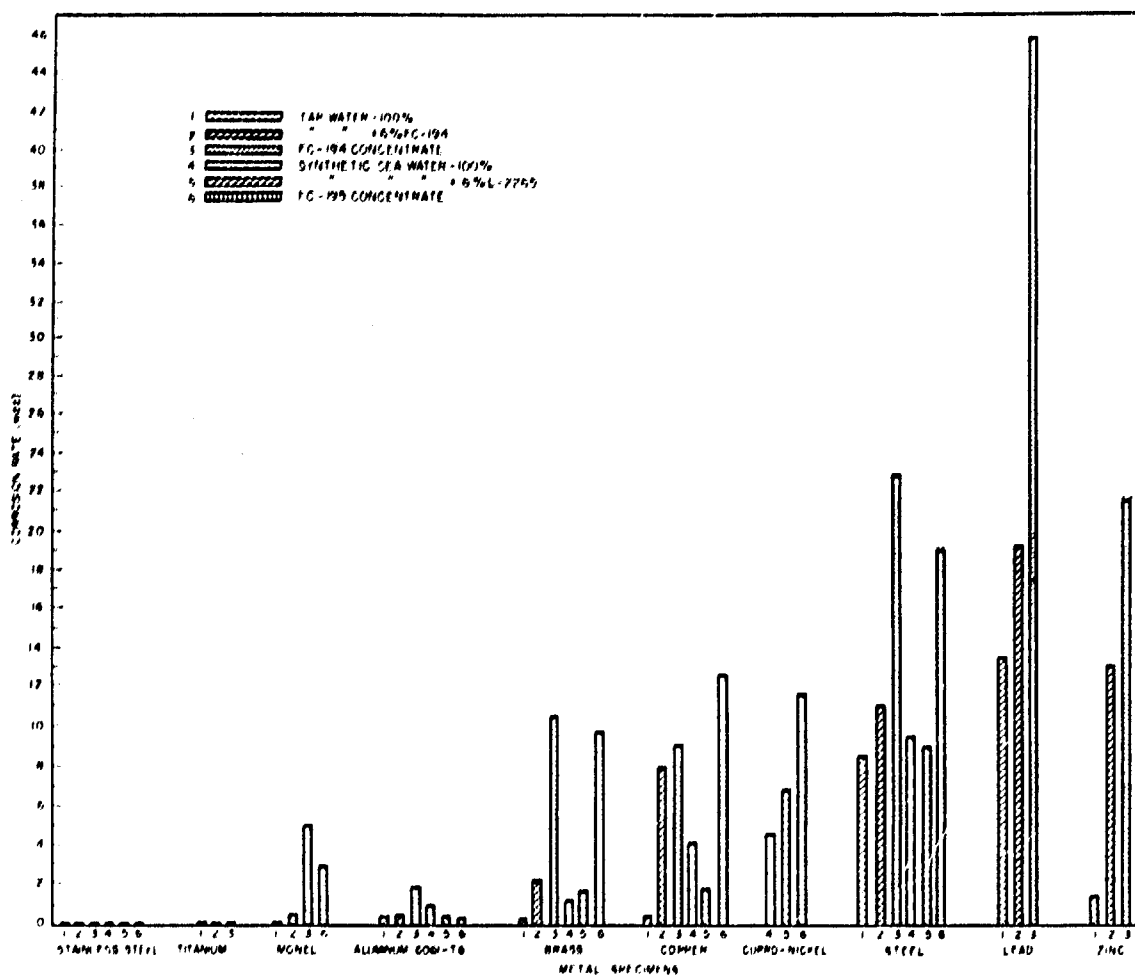


Fig. 1 - This chart shows the corrosion rates (weight losses in milligrams per square decimeter per day-mdd) of metal specimens by metal type. We see that steel and lead, for example, are generally more susceptible to corrosion by the test liquids than are stainless steel or titanium. FC-194 and FC-195 (same as L-2265) are two formulations of a fire-extinguishing agent.

The rate of attack on steel by all liquids was greater than that of the metals previously discussed. The 0% Light Water solutions were only slightly more corrosive than the two types of water used in their preparation. The concentrates produced the greatest losses, in the range of 18-22 mdd.

Lead and zinc suffered losses on the order of steel, or slightly higher. These metals would not be expected to be found on shipboard in contact with Light Water in any form. The relatively high loss rates of zinc would further indicate that high-zinc-content alloys should also be avoided.

#### Metal Couples

Inasmuch as the metal couples composed of cupro-nickel paired with bronze, stainless steel, monel, brass, or copper, and which were brazed by shipboard fabricating techniques,



showed no evidence of galvanic corrosion when immersed in Light Water concentrate, it is believed that there is no concern in this area in shipboard installations.

#### Comparison of the Liquids

In comparing the liquids, the FC-195 Light Water concentrate was slightly less corrosive toward four of the metals exposed and slightly more corrosive toward one metal. There was very little difference in corrosive activity between the four experimental formulations of FC-195, as shown in Fig. 2.

Tap water showed little corrosive activity, except on steel and lead. Sea water demonstrated more activity than tap water on copper and cupro-nickel.

In general the 6% Light Water solutions were practically the same as their water diluent counterparts from a corrosive standpoint, and less corrosive than their Light Water concentrate counterparts.

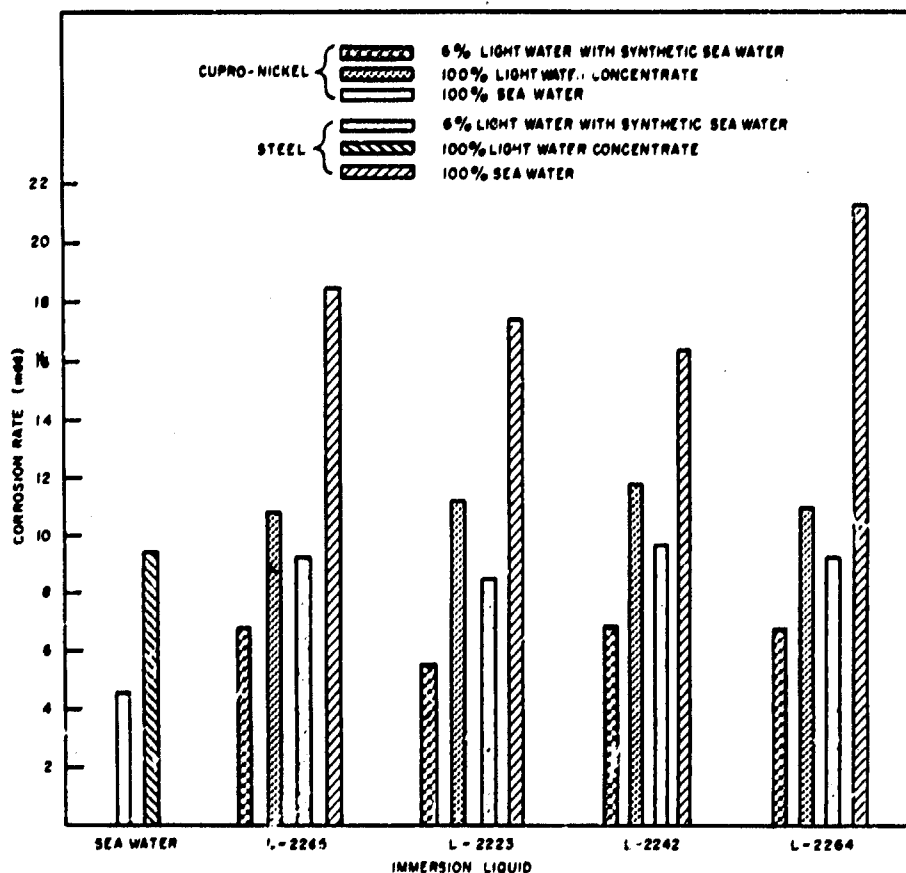


Fig. 2 - The corrosion rates (weight losses in milligrams per square decimeter per day-mdd) of cupro-nickel and steel specimens are grouped according to the type of liquid in which the specimens were immersed. The liquids prefixed by an L are experimental formulations of the fire-extinguishing agent Liquid Water. As can be seen, there is very little difference in the corrosive activity of the four experimental formulations.

### Storage Tank Construction for the Concentrate

The shipboard fire-fighting system requires large capacity tanks, 300-600 gallons, for the storage of Light Water concentrate to supply an injecting pump which feeds branches of the fire main. These tanks, pump suction lines, and pumps will be continually wetted by concentrate. If the mdd values from Fig. 1 are expressed on a milli-inches-per-year (mipy) basis, a value may be obtained indicating the rate of linear metal removal by the concentrate. This could be called a uniform penetration rate and is a guide for projecting the life expectancy of a tank wall. The following table summarizes the estimated life of concentrate storage tanks fabricated of metal 3/16 in. in thickness:

Metal	Corrosion Rate for Concentrate		Estimated Life (yr)
	(mdd)	(mipy)	
Stainless steel	0	0	Infinite
Titanium	0.07	0.03	Infinite
Monel	2.9	0.5	300
Brass	10.6	1.8	105
Cupro-nickel	11.8	1.8	105
Steel	18.2	2.7	65

On the basis of life expectancy only, any of the above metals should prove satisfactory for the storage and handling of Light Water concentrate. However, steel is not recommended because of the tendency for it to form rust and scale which might interfere with fluid flow. Also, as pointed out previously, stainless steel tanks must be fabricated with special caution.

Although stainless steel is approximately four times the basic cost of cold-rolled steel, it is estimated that the finished stainless steel tank would cost only 30% more than ordinary steel because of the extra labor costs involved in fabricating an ordinary steel tank.

Protective coatings for lining steel tanks have not been investigated as a part of this study, but it is believed that coatings offer another possible solution to the corrosion problem. The 5-gallon pails now used for shipping and handling of Light Water concentrate are made of steel, lined with an epon-phenolic resin, and have been found to give satisfactory service.

The Light Water concentrate used on naval aircraft fire-fighting and rescue vehicles, such as the MB-1 and MB-5, and which was purchased prior to 1968 is stored in the stainless steel tanks previously used for the protein foam concentrate. Since first conversions were made only about two years ago, a long history of the effect of the concentrate on the tanks is not available at the time of this writing.

### Piping Construction for the Solution

The piping supplying the flush deck nozzles, deck edge nozzles, or foam water sprinkler nozzles on an aircraft carrier will handle only the dilute 6% solution of Light Water. With the present protein-type foam installations this piping is normally dry, but with the

proposed Light Water installation this piping will be constantly wetted by the 6% solution. The solution corrosion rates from Fig. 1 and the calculated expectancy for 1/8-in. wall piping materials are as follows:

Metal	Corrosion Rate for 6% solution		Estimated Life (yr)	Corrosion Rate for Sea Water (mdd)
	(mdd)	(mipy)		
Stainless steel	0	0	Infinite	0
Brass	1.7	0.3	400	1.4
Cupro-nickel	6.8	1.1	110	4.6
Steel	9.3	1.4	90	9.5

From the above table it may be judged that any of the listed metals would be satisfactory for handling the solution. The cupro-nickel alloy now used for shipboard fire mains would be only slightly less resistant to the 6% solution than to the sea water presently in them. These life expectancies are based on static corrosion exposure tests. This is taken as being a valid projection method because flow in these portions of the fire mains takes place only at the time of an actual fire or system tests, a total of only a few minutes per year. Many portions of the ship's fire mains carry sea water for everyday uses and may have continuously high water velocities within. This would account for the observed failure of cupro-nickel fire main piping in less than the above projected figures. Moving water is more destructive because it acts to remove the protective films which form on the metal surface and because the solid particles in the stream create an erosive action.

As cited above, dilute Light Water solutions are currently being stored in aluminum alloy and stainless steel containers in naval fire-fighting apparatus. The first units using aluminum tanks were introduced in 1964 and there are no known instances of problems with this arrangement. Aluminum spheres were used for this application mainly in the interest of saving weight rather than for corrosion considerations. In the most recent procurement of vehicle-mounted units, welded stainless steel tanks were used. These tanks reached the field early in 1968, and no reports have been received on them as yet.

Fire apparatus built for civilian applications of the Light Water solution have featured a baked phenolic resin lining on steel, with apparently good results.

#### Corrosion Tests by Others

The Minnesota Mining and Manufacturing (3M) Company has conducted corrosion tests on Light Water and related materials according to the procedures contained in the current federal specification for protein foam (8) and by use of the Petrolite Corrosion Rate Meter. They have reported their results\* in a range of observed values as follows:

\*Private communication (see Ref. 2).

Liquid	Corrosion Rate (mdd)				
	Stainless Steel 302	Brass	Cu-Ni	Alum 6061	Carbon Steel
Tap Water	0	1.6	0.3	0.5	7-9
Sea Water	0	1.7	4.6	1.4	9-11
FC-195 Conc.	0	1-10	12-20	0.2-3.0	8-19
FC-194 Conc.	0	1-5	-	4	4-8
6% FC-195/tap	0	2.4	-	0.3	2
6% FC-195/sea	0	3	7-20	0.8	2-10
6% FC-194/tap	0	5	-	1-3	2-12

Note: Aluminum exhibited localized pitting.

The laboratory at the Naval Air Rework Facility conducted corrosion tests on 6% solutions (fresh water) of FC-194 (2). They concluded that the solution would corrode aluminum on long-time exposure but that the corrosion rates on black iron and brass were less than with tap water itself.

#### Protein Foam Corrosion

Several years ago this Laboratory conducted a study of the corrosion characteristics of protein-type foam concentrates (3). At that time it was determined that the corrosivity varied not only from manufacturer to manufacturer but also from batch to batch. Presumably this was because of changes being made in the chloride and ferric salt contents. The results from one of the most corrosive protein foam concentrates were as follows:

Metal	Corrosion Rate (mdd)
Aluminum 1100	96
Aluminum 5052	35
Brass	34
Copper	19
Stainless Steel 304	-
Steel, CR	134

The findings of this study gave impetus to the need of inserting a corrosion limit requirement in the protein foam specification and this was done for steel in Federal Specification O-F-555a. Several activities have also recommended that a corrosion limit for aluminum be included, but this has never been accomplished.

The current allowable corrosion rate for protein-type foam concentrate on steel is 30 mdd, according to Federal Specification O-F-555b (8). The procedure used in this specification is similar to that used in the current work except that total immersion of the metal specimen in the liquid is required. The ultimate effect of this difference in procedure is not known. The mdd is based on the wetted area and the period of immersion so the differences in depth and time should cancel out. Concentration of corrosive

activity at the air-liquid interface with the partially immersed specimens as used at NRL could well have resulted in values in error on the high side for Light Water concentrate for purposes of comparison with protein concentrates.

The extremely dark color and opacity of the protein foam concentrates preclude the observation of the presence of metal ions in solution, and also of other accompanying by-products of corrosion.

The protein foam concentrates were found to promote galvanic corrosion.

#### Specified Limits on Light Water Corrosiveness

The new specification being prepared for a sea water/fresh water Light Water concentrate sets forth maximum corrosion rates for steel, aluminum, and cupro-nickel (8). The requirement for cold-rolled steel is that the corrosion rate with the concentrate shall not exceed 25 mdd; 6061 aluminum with concentrate shall not exceed 0.5 mdd; and 90-10 cupro-nickel with a 6% concentrate/sea water solution shall not exceed 10 mdd. These requirements are based on the same procedure as used in obtaining the values presented in Fig. 1 and are directly comparable to those values.

The above limits set forth for Light Water will ensure a product less corrosive than the present protein-type foam.

#### Other Test Procedures

A deterrent to the accumulation of more corrosion test data has been the time period required for sample exposure. The present procedure was arbitrarily set for 38 days. There are on the market corrosion rate meters arranged to give a direct and immediate meter reading of the corrosion rate in mils per year. One of these is the Petrolite Corrosion Rate Meter which determines the current flow required to polarize a test electrode in a liquid. By Faraday's Law the rate of metal loss is directly proportional to this electrical current. Such a device could be of great value in studying the corrosion of Light Water. However, as of this date, not enough confidence has been built up in this method to warrant purchasing a rate meter for evaluation as a potential standard. The 3M Company has tried one type of meter and was not completely satisfied with the correlation between the meter results and long-time-exposure weight loss results. Currently there are no plans for using any procedures other than the one set forth earlier in this report.

A major shortcoming of the corrosion data obtained to date is the lack of insight into the rate of change of the rate of corrosion. All values in this report are predicated on the assumption that the rate is a straight linear (i.e., constant) function and may be extrapolated to great lengths of time. Such is not necessarily the case. The observed rates may drop off over a period of time as protective corrosion barriers build up, or conversely, the rate may accelerate after prolonged exposure. The use of a single fixed time period can yield no information toward detecting a changing in the corrosion rate itself.

#### Procurement of Metal Specimens

A second deterrent to building a broader base of corrosion test data is the difficulty in obtaining specimens of various metals which are of interest. The variety of metals in NRL stocks is limited, and information as to their alloy composition is usually nonexistent.

Inquiries to metal producers for samples of copper alloys such as the Navy's cupro-nickel were fruitless. So, the cupro-nickel samples used in the tests were prepared from sections of pipe obtained from the Naval Shipyard, Philadelphia. New sources of metal samples would be desired.

#### Modified Concentrate Samples

A third deterrent to building a backlog of corrosion data has been the development of the concentrate formulation. Although a product has been developed which fully meets the minimum performance requirements for a sea-water-compatible Light Water concentrate, continuing efforts were, and are, being made to upgrade the performance by chemical modifications. It is not anticipated that these relatively minor modifications have changed the corrosive characteristics, but it is highly desirable to begin taking data on the most recent product because of the long time required for obtaining meaningful weight loss data.

#### Fire-Fighting Considerations

Aside from the attack of the liquids on exposed metals, which does not appear to be a difficult problem to alleviate, there is the potential problem of reaction between the liquids and the metals which might affect the foaming and fire-fighting performance of the agent. By visual observation of the exposure samples it was noted there was some reaction between the metals and the liquids. This was evidenced by the characteristic metallic ion coloration in the liquids and by the formation of varying amounts of sludge or solids. The latter could be a problem through the mechanical blocking of pipes, nozzles, orifices, proportioners, etc. The former could be a problem through chemical interference or "poisoning" of the Light Water. At this time there is no reason for thinking that either of these reactions is generating a problem, but these possibilities should be investigated further. Here again time is a big factor because the liquids should be exposed to the metals for periods up to a year for proper evaluation. At present there are no known procedures for accelerating these immersion tests.

#### Reaction with Ancillary Materials

The 3M Company has conducted compatibility tests between FC-194 and the elastomers neoprene (chloroprene), nitrile (butadiene acrylonitrile), and EPT (ethylene propylene terpolymer) and has found all combinations to be satisfactory with respect to sample volume swell and permanent set, tensile strength, elongation, hardness, and adsorption tests. The 3M Company also reported that asbestos and metallic pump seals were satisfactory for use with FC-194 and that Ace Lube Lithium HD<sub>2</sub> was satisfactory as a water pump grease.

#### Future Work

Current production runs of aircraft fire-fighting and rescue vehicles for the Naval Air Systems Command are using plastic-reinforced fiber glass tanks for the storage of Light Water concentrate. A Koppers Company polyester resin with a gel coat lining on fiber glass is being used with apparently good results. A tank of this type should be excellent for shipboard installation from the standpoint of corrosion resistance and freedom from agent contamination. (The suitability of such a tank in regard to shock resistance and other mechanical problems which might be unique to shipboard use are not known.) Along with plastic materials for reinforced plastic tanks, the use of plastic pipe,

plastic-lined metal pipe, and plastic-lined iron valves should be evaluated. (The Cla-Val Company makes iron plastic-lined Hytrol and Power-trol valves like those used in the aircraft carrier fog-foam systems.)

Several manufacturers of plastic materials used for reinforcing fiber glass for tanks have been contacted and have furnished samples of resins\* which they would recommend for service with Light Water concentrate. Exposure tests of these resin samples are presently underway at NRL.

An effort has been made to find plastic materials not only suited for Light Water service but which will meet the requirements for these existing specifications: MIL-T-19247A(SHIPS)-Tank, Liquid Storage, Non-Metallic, Marine Oil and Water Service, and MIL-R-21607-Resins, Polyester, Low Pressure Laminating, Fire Resistant.

Future work in the area of materials for the storage and handling of Light Water should be devoted in the main to increasing knowledge on the use of nonmetallics.

## CONCLUSIONS AND RECOMMENDATIONS

The corrosive action of a 6% FC-195 Light Water/sea water solution is almost nil toward type 304 stainless steel and has a corrosion rate of 7 milligrams per square decimeter per day (mdd), or lower, for cupro-nickel, brass, and other high-copper alloys. This corrosion rate is essentially the same as that of sea water for the metals tested. Therefore, the continued use of cupro-nickel piping for the distribution of fire-fighting agent solutions appears to be justified.

The corrosive action of the concentrated FC-195 Light Water is somewhat greater than its dilute sea water solution. The corrosion rates varied from zero with type 304 stainless steel to 12 mdd with copper alloys to 18 mdd with cold-rolled steel. If it is desired to use metal tanks on shipboard installations for concentrate storage, stainless steel should be considered. But proper attention should be given to fabrication techniques involving stainless steel to prevent corrosion sensitization; one technique might possibly involve heat treatment after welding. Even though the cost of stainless is four times that of steel per pound, it is estimated that the final cost of the finished stainless steel tank would be only 30% higher. Brass or stainless is recommended for piping and pumps when metal is desired. Other metals that have a high corrosion resistance when tested with FC-194 Light Water concentrate are titanium and monel. Both showed insignificant evidence of surface destruction and had relatively low corrosion rates.

The corrosion rate of protein foam concentrate has been found to be about 13 times higher than Light Water concentrate toward steel, and about 2.0 times higher toward brass. Federal Specification O-F-555b permits a steel corrosion rate of 30 mdd, which is twice as high as that found for FC-195 in the present tests.

The use of plastics, glass-reinforced plastics, and plastic-lined metal parts is recommended for handling Light Water concentrate on shipboard, where structural considerations permit.

In view of the urgent need which has been expressed for improved fire fighting on aircraft carriers, the possibility of putting Light Water in existing High Capacity Fog Foam systems should not be overlooked. The present use of black iron concentrate storage tanks is the most uncertain factor; these tanks could be replaced in the field fairly easily with plastic or lined metal tanks.

\*Hooker Chemical Co. (hetrons 92, 194, 197, and 355), Koppers Chemical Co. (resins 1060-5, 6060-5, 3300-5, and 3463-5), and Read Plastics Inc. (resin 3463-5).

## REFERENCES

1. Tuve R.L., Peterson, H.B., Jablonski, E.J., and Neill, R.R., "A New Vapor-Securing Agent for Flammable-Liquid Fire Extinguishment," NRL Report 6057, March 1964
2. "Light Water Corrosion Report," Naval Air Rework Facility, Naval Air Station, North Island, California, Dec. 7, 1967; also, Minnesota Mining and Manufacturing Company, private communication, August 1968
3. Peterson, H.B., and Burnett, J.C., "The Corrosive Effects of Protein-Type Foam-Forming Concentrates on Common Metals and Dissimilar Metal Couples," NRL Report 4947, June 1957
4. "Fire Extinguishing Agent, 'Light Water' Liquid Concentrate, 6 Percent, For Fresh and Sea Water," Federal Specification dated February 18, 1969 (superseding MIL-F-23905B(AS), dated April 25, 1967)
5. "Standard Specifications for Substitute Ocean Water," 1968 Book of ASTM Standards, D 1141-52 (reapproved 1965), part 23, pp. 206-208
6. "Standard Method of Total Immersion Corrosion Test of Stainless Steels," 1968 Book of ASTM Standards, A 279-63, part 3, pp. 268-276
7. "Recommended Practice for Conducting Plant Corrosion Tests," 1968 Book of ASTM Standards, A 224-46 (reapproved 1961), pp. 150-158
8. "Foam-Forming Liquids, Concentrated Fire Extinguishing, Mechanical," Federal Specification O-F-555b, dated March 11, 1964 (superseding Int. Fed. Spec. O-F-00555a (NAVY - Ships), dated March 17, 1961)



## DOCUMENT CONTROL DATA - R &amp; D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Research Laboratory Washington, D.C. 20390		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP	
3. REPORT TITLE CORROSION RESISTANCE OF SOME COMMON METALS TO CONCENTRATED AND 6% SOLUTIONS OF LIGHT WATER FIRE-EXTINGUISHING AGENT			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Interim report; work on the problem continues.			
5. AUTHOR(S) (First name, middle initial, last name) A.W. Bertschy and H.B. Peterson			
6. REPORT DATE August 8, 1969		7a. TOTAL NO. OF PAGES 18	7b. NO. OF REFS 8
8a. CONTRACT OR GRANT NO. NRL Problem C05-19 b. PROJECT NO. SF 015-07-02-3350 c. Subproject S 4643, Task 12081 d.		9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 6932 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10. DISTRIBUTION STATEMENT This document has been approved for public release and sale; its distribution is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Dept. of the Navy (Naval Ship Systems Command) Washington, D.C. 20360	
13. ABSTRACT A study has been made concerning the corrosion resistance of a group of common construction metals that might come in contact with the fire-extinguishing agent known as Light Water. The metals examined were exposed to concentrated Light Water material and to 6% solutions of Light Water prepared with sea water and with fresh water.  Type 304 stainless steel and titanium were virtually unaffected by any of the liquids. Overall weight losses for type 6061 aluminum alloy were low, on the order of 2 milligrams per square decimeter per day (mdd). However, localized pitting was observed. Monel had losses of 5 mdd with the Light Water concentrate. The copper-base metals immersed in the concentrate exhibited weight losses in the range of 10-13 mdd, while steel, lead, and zinc were in the 18-40 mdd range.  The corrosive effect of 6% solutions prepared with fresh water was generally not different than with fresh water itself, except for the copper-base alloys. The 6% solutions prepared with sea water gave results generally not different than with sea water itself.  —Continues			

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fire extinguishing agents Corrosive liquids Immersion tests (corrosion) Stainless steel Titanium Aluminum alloys (6061) Steels Lead(metal) Zinc Copper nickel alloys Copper Monel						
<p>A comparison of the Light Water concentrate test results with earlier tests conducted on protein-type foam concentrates shows the latter to be considerably more corrosive. The limits for corrosion as set forth in the proposed military specification for Light Water fire-extinguishing concentrate are lower than those in the current federal specification for protein foam concentrate.</p>						